Selenga Delta, Lake Baikal, Russia

10 Km

Deltas provide a multifaceted record of past environmental conditions

Woody Fischer (Caltech) & Ralph Milliken (Brown)

Geological and Geobiological value of ancient deltas

1. Sedimentology & Stratigraphy

- paleoenvironmental reconstruction
- water and sediment fluxes and their time variation

2. Sediment Provenance & Composition

- weathering and erosion
- "Noachian" shale composite (Taylor & McLennan 1985)

3. Organic Carbon Preservation

- fine-grained sediment, rapid sedimentation

4. Authigenic Phases

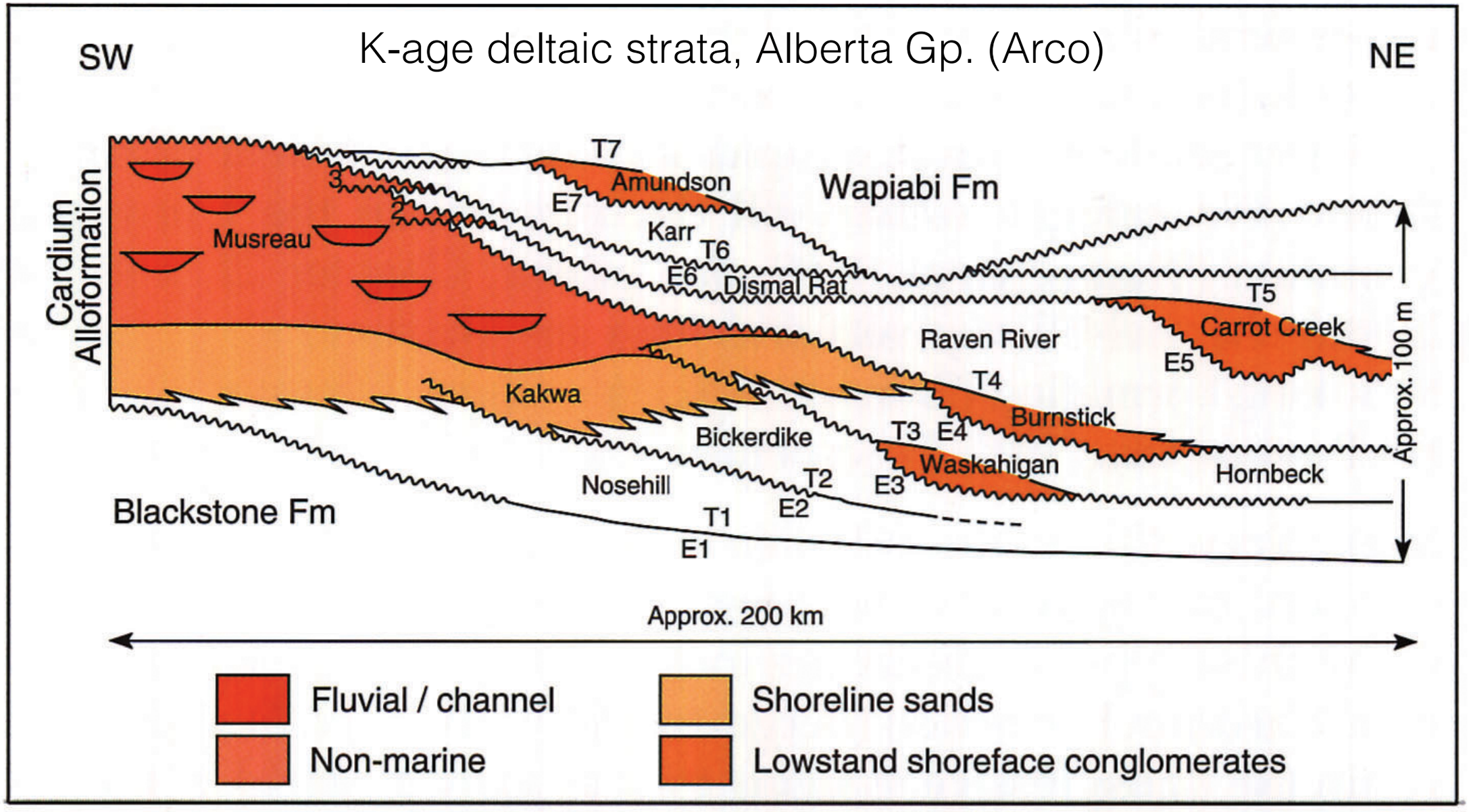
- redox chemistry and element cycling (e.g. iron formation)
- climate (e.g. carbonates, isotopes)

Fluvial deltaic sedimentary rocks provide an unambiguous measure of the activity and work done by ancient water and the atmosphere at the planet's surface.

Architecture of the delta stratigraphy informs: accommodation, lake level, water & sediment supply.

The resulting deposits provide a geological archive of denudation and mass flux into any given sedimentary basin.

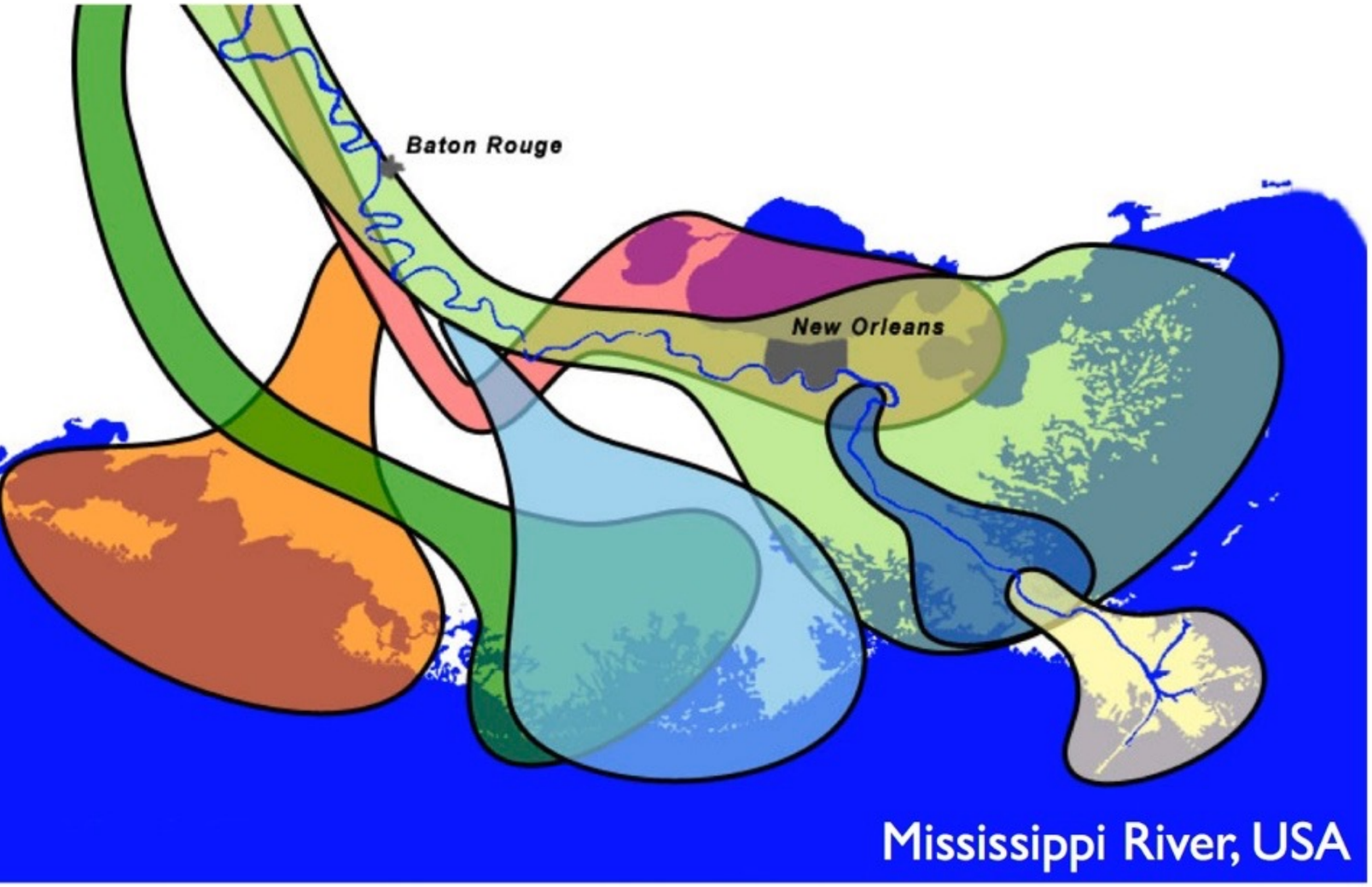
Stratigraphic context for organic phases



Organic matter is naturally well-preserved in deltas.

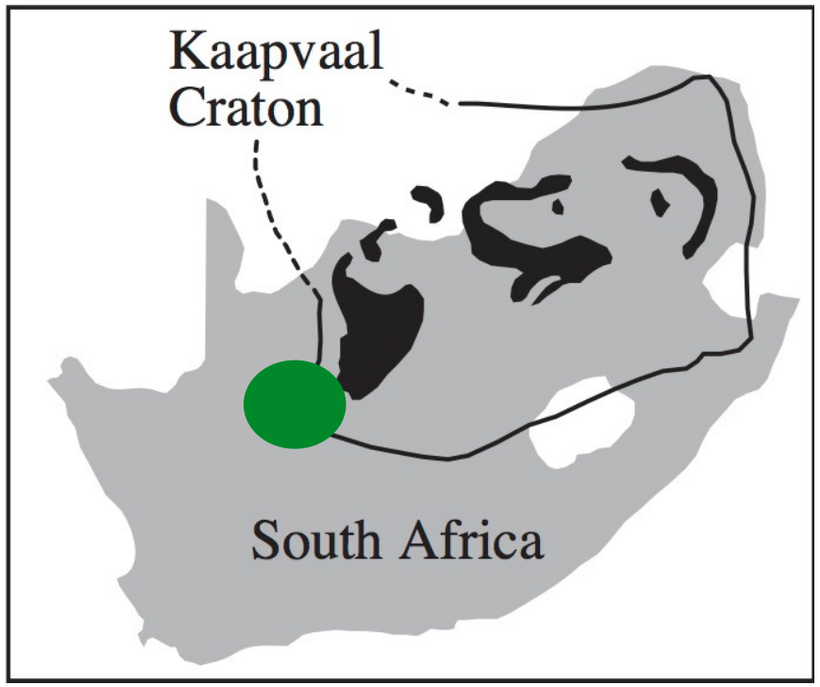
- molecular association with fine-grained particles
- sedimentary removal from surface radiation and oxidants

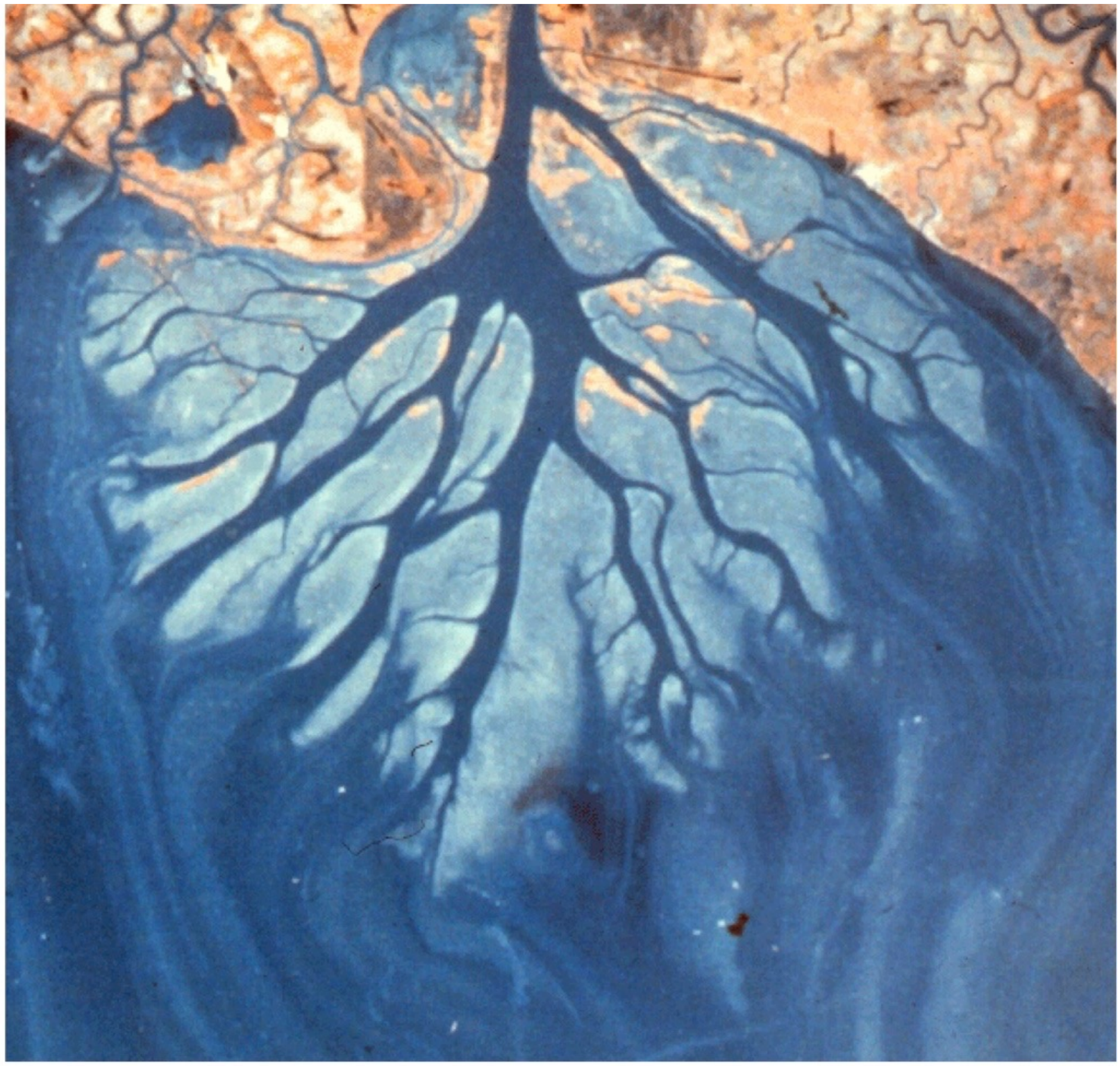
Delta lobe-switching and deposition of authigenic phases

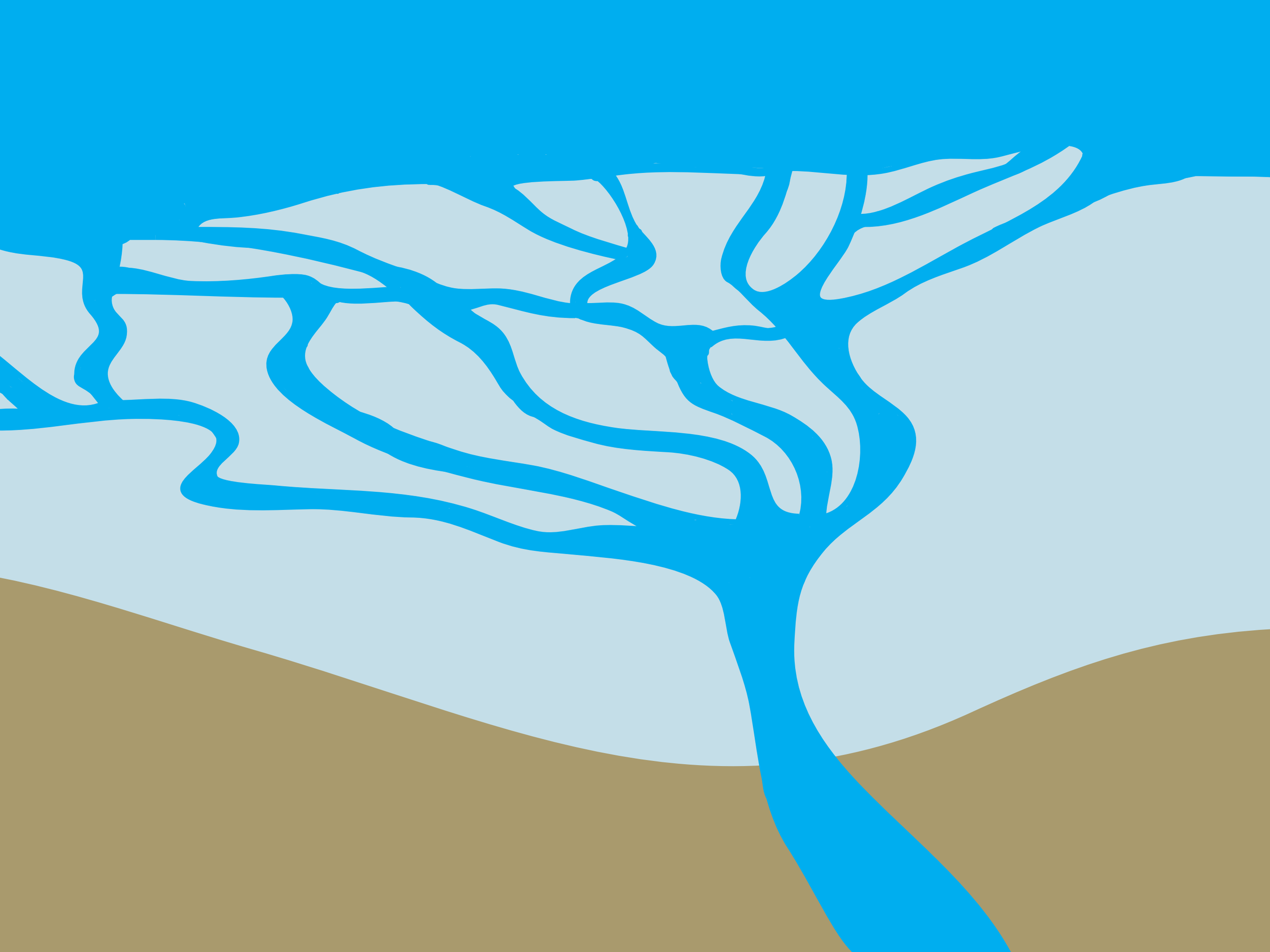


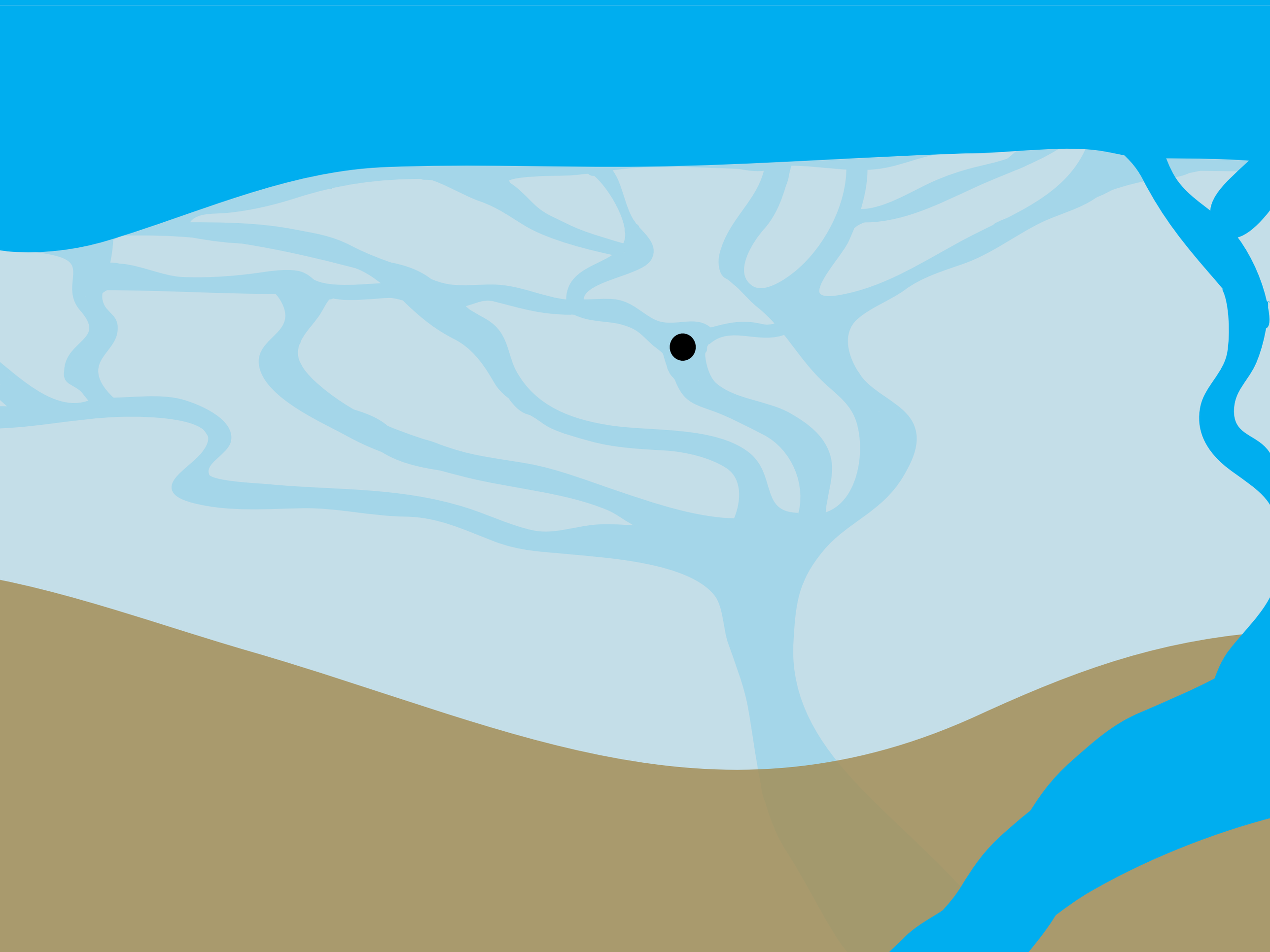
Coleman, 1988; Nasa Earth Observatory

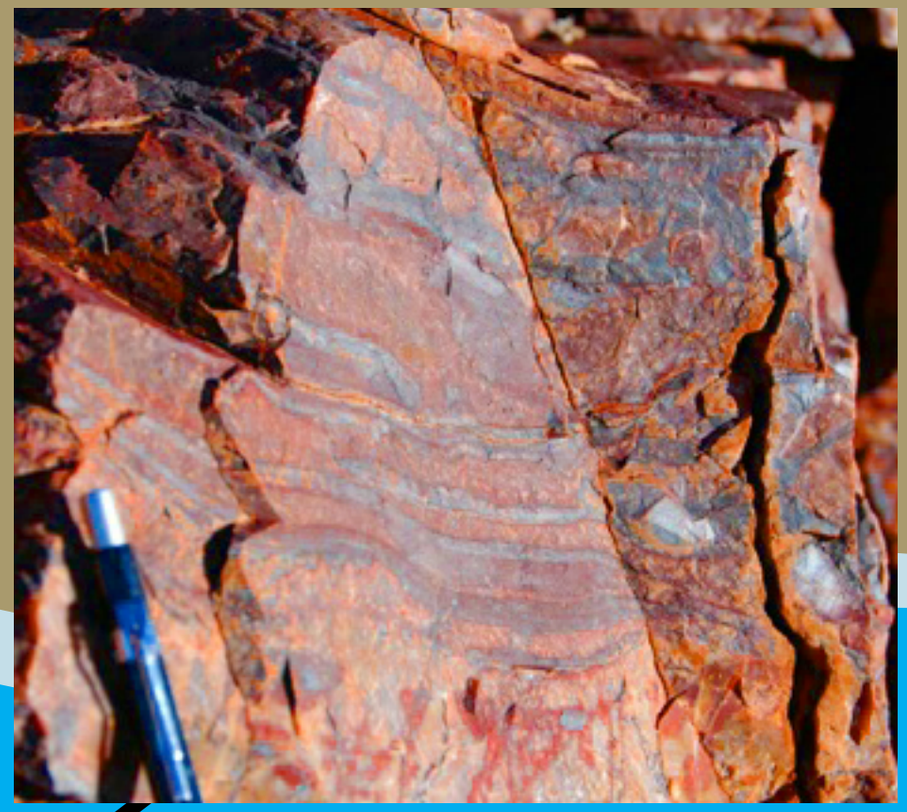
Late Archean - early Paleoproterozoic Transvaal Supergroup







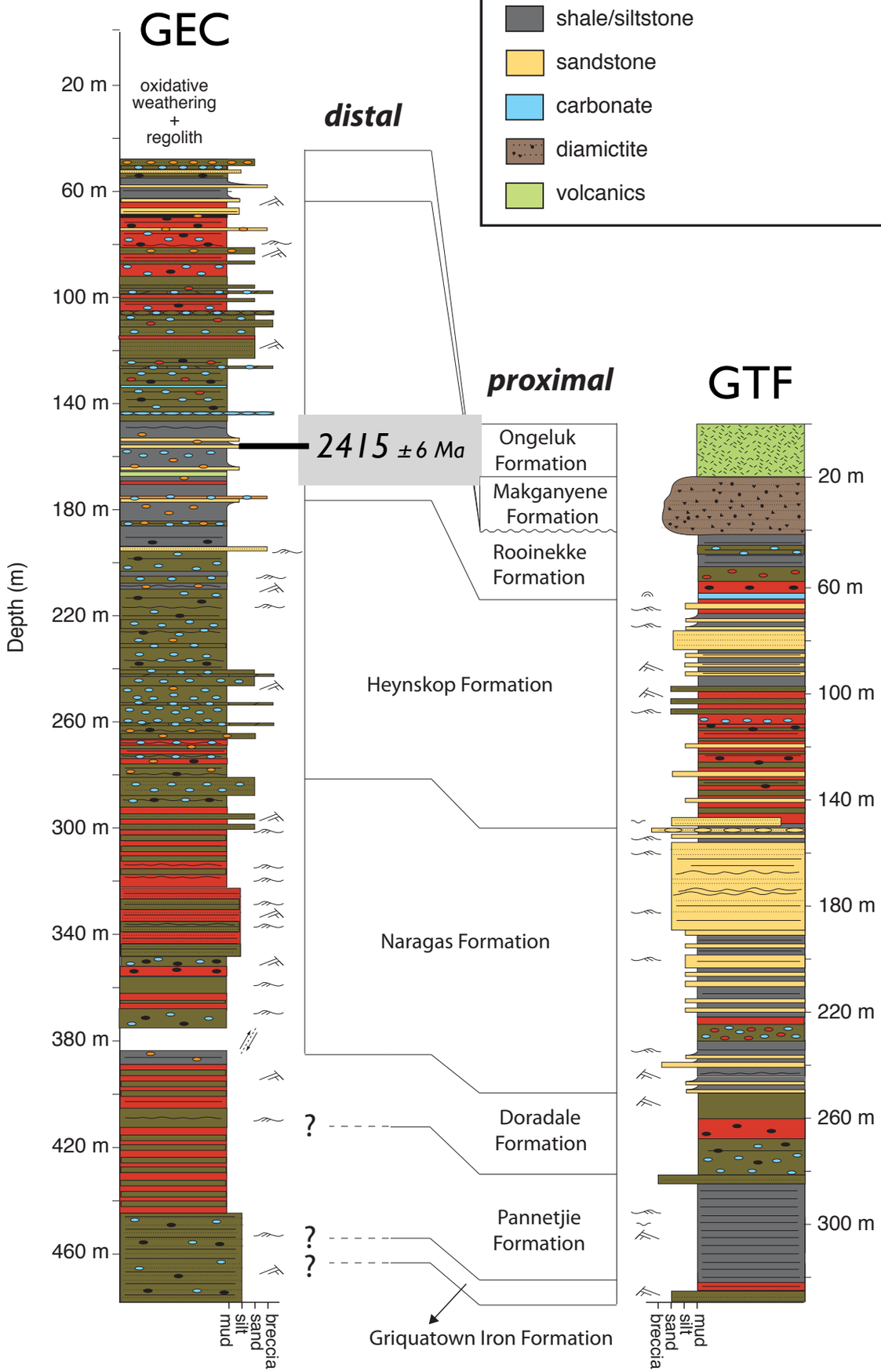




GTF

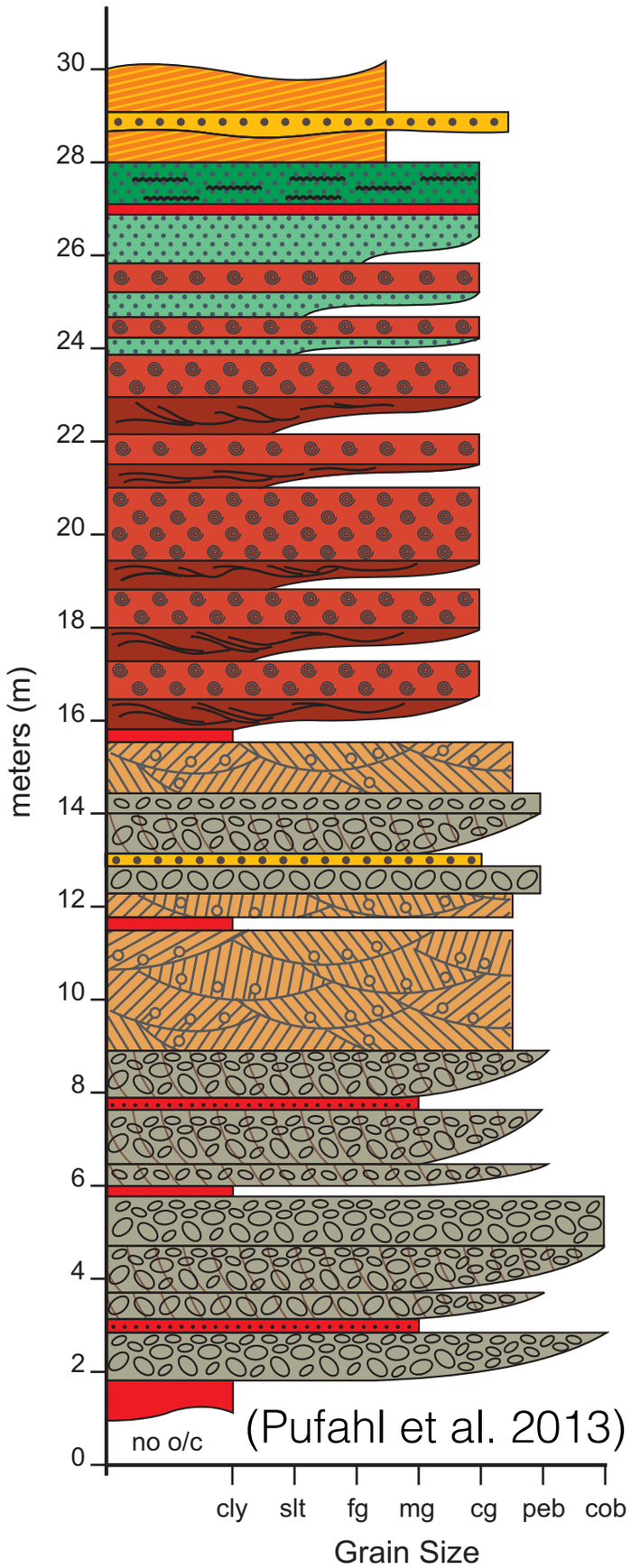
> 50 km

GEC

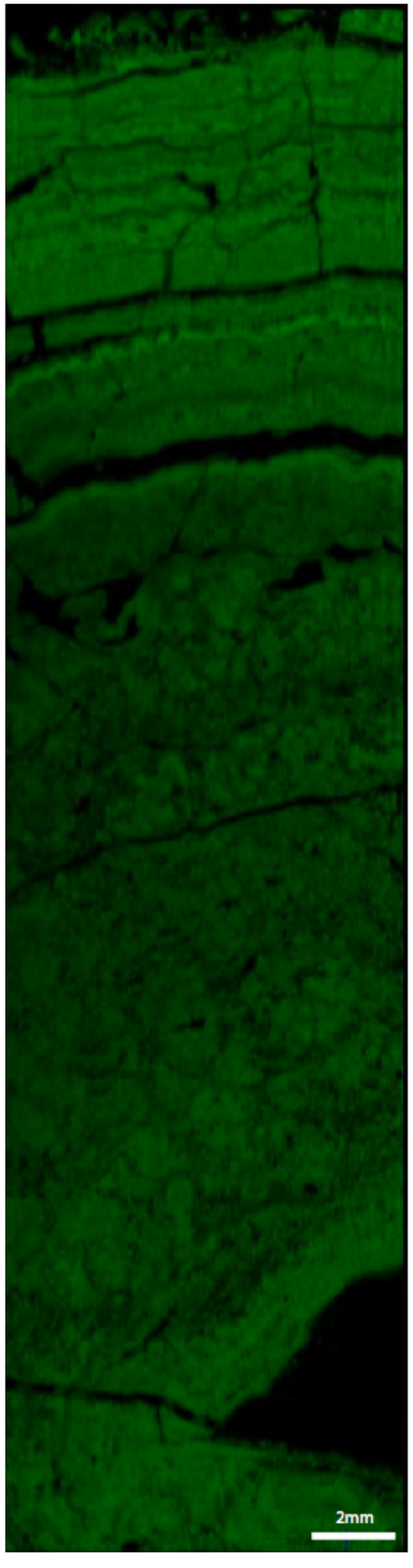


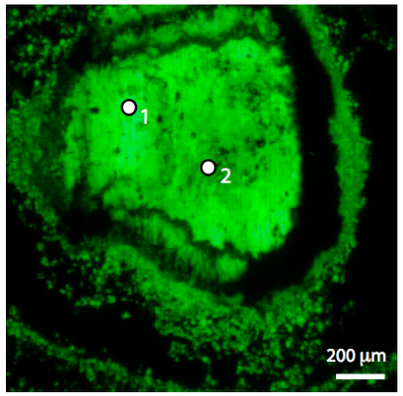
Johnson et al. 2013

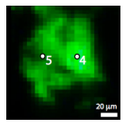
Paleoproterozoic deltaic iron formation - Western Australia

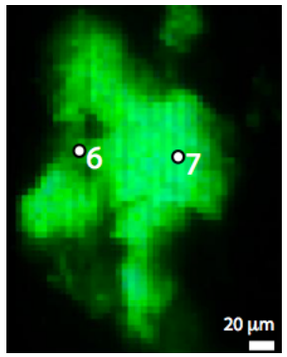


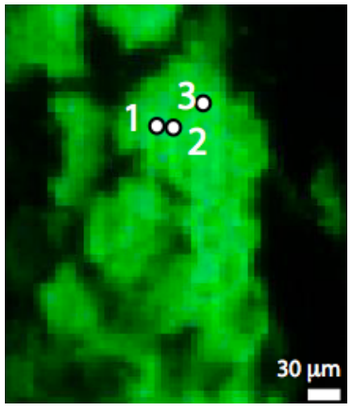
Post-depositional reduction of Fe & Mn-oxides is common in deposits.

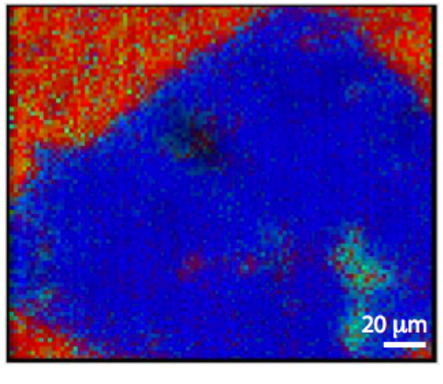


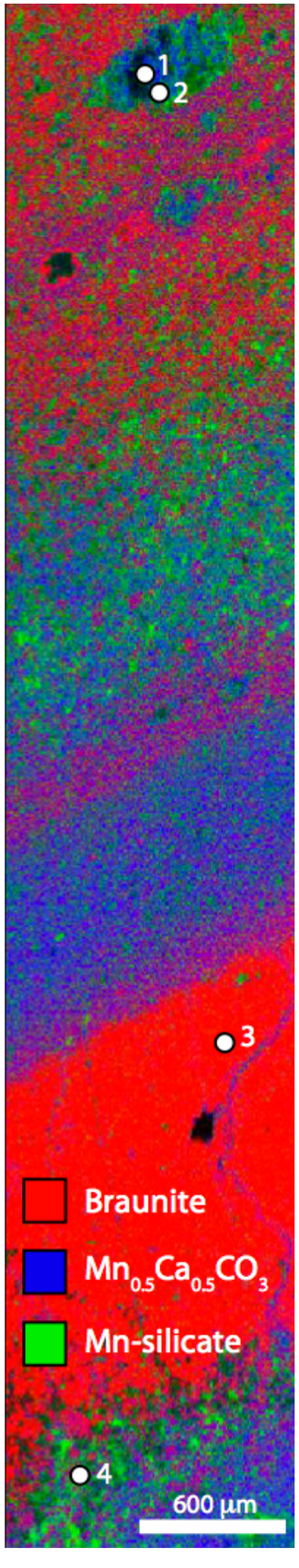


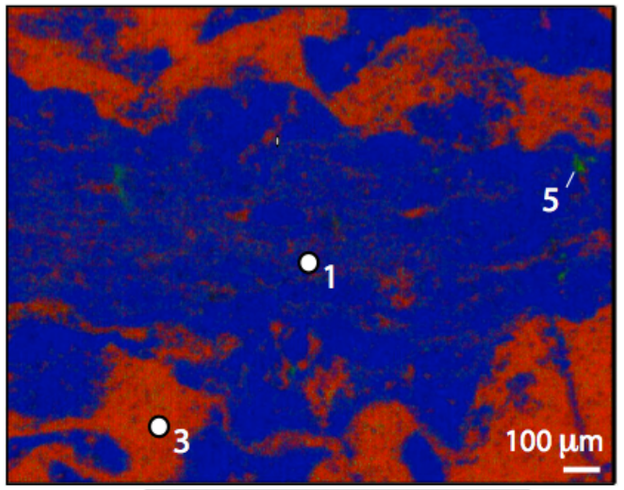


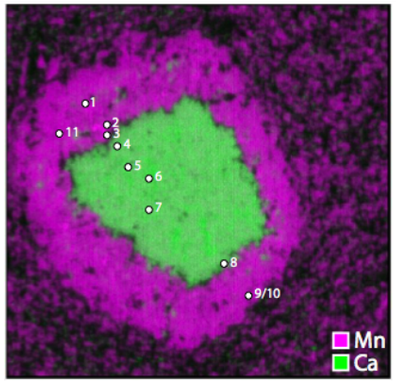


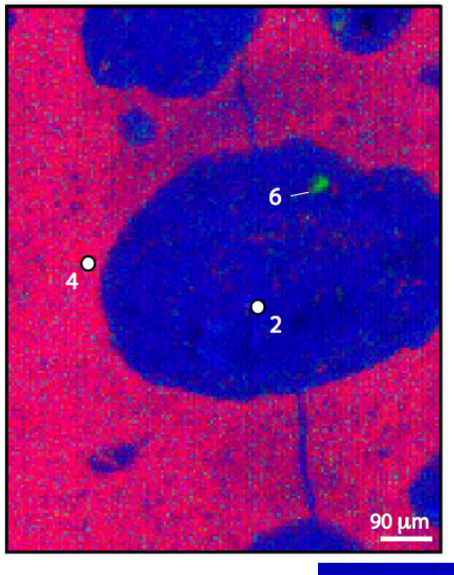


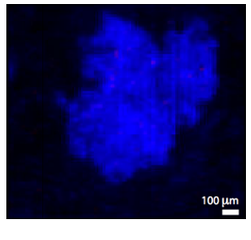


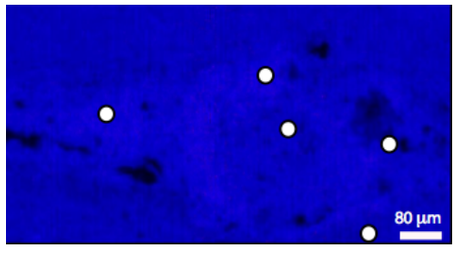


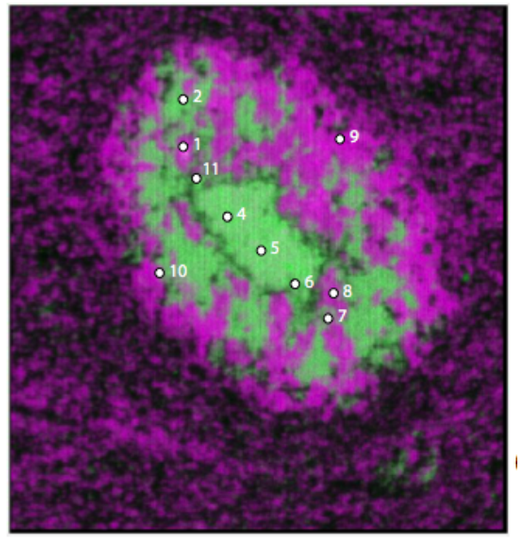


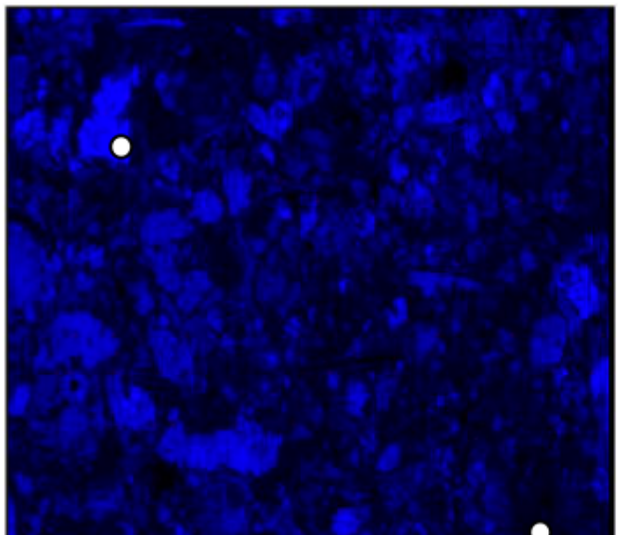


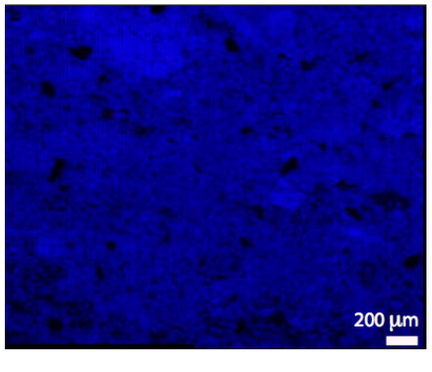








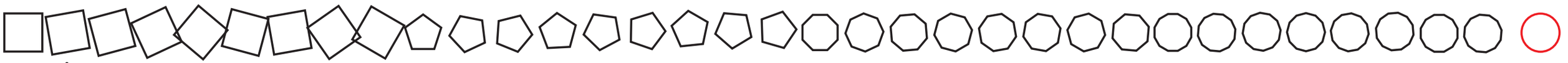




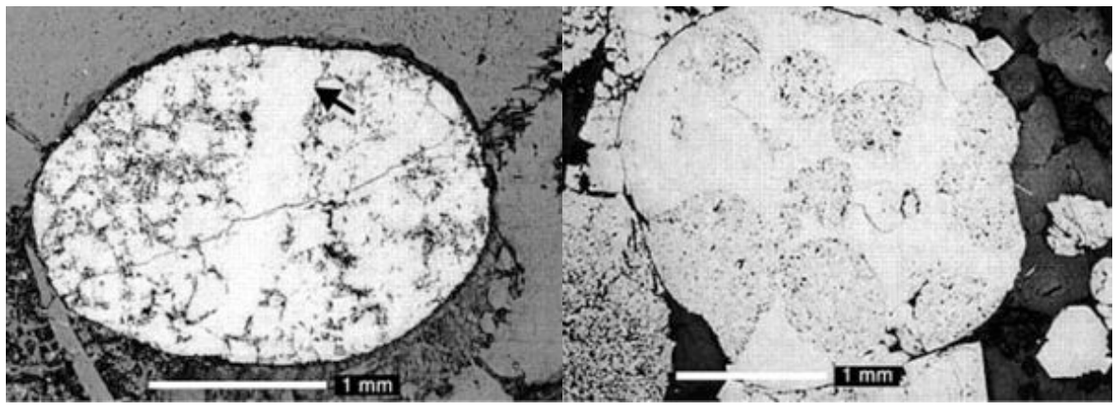
Authigenic sedimentary minerals that accumulated in deltaic environments provide an important archive of ancient redox processes, water chemistry, and element cycling.

Redox-sensitive detrital grains

oxic

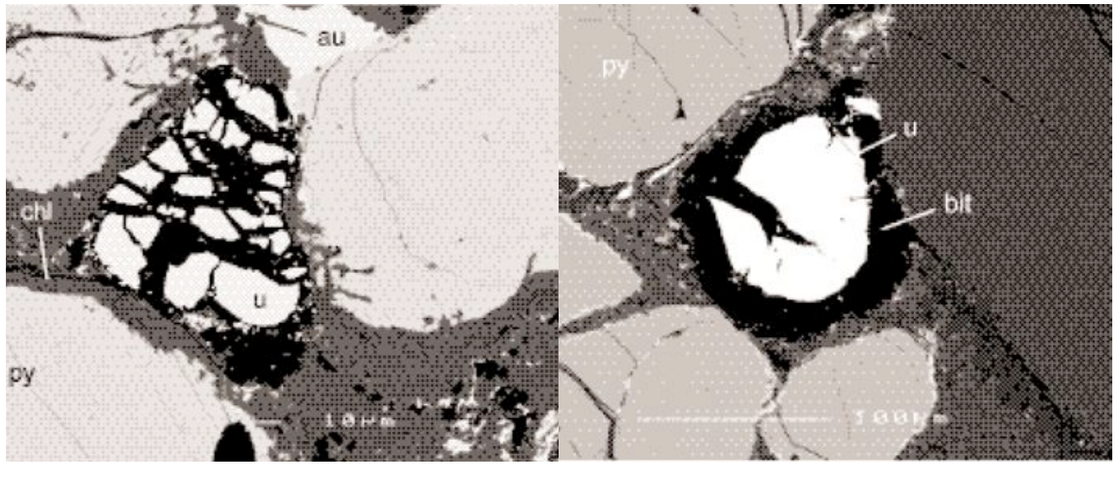


anoxic



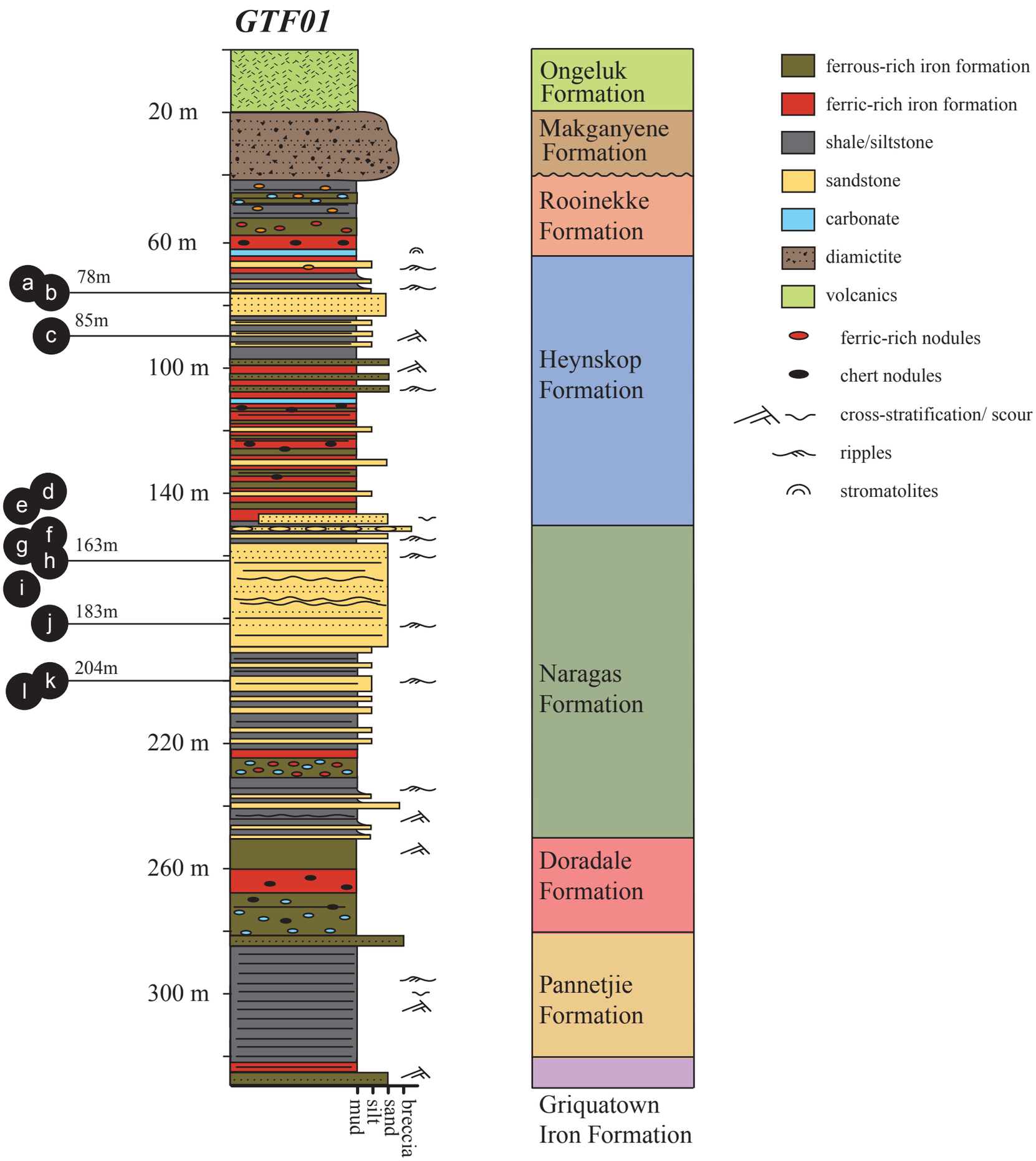
Pyrite

$$FeS_2 + {}^{7}/_{2}\,O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+$$

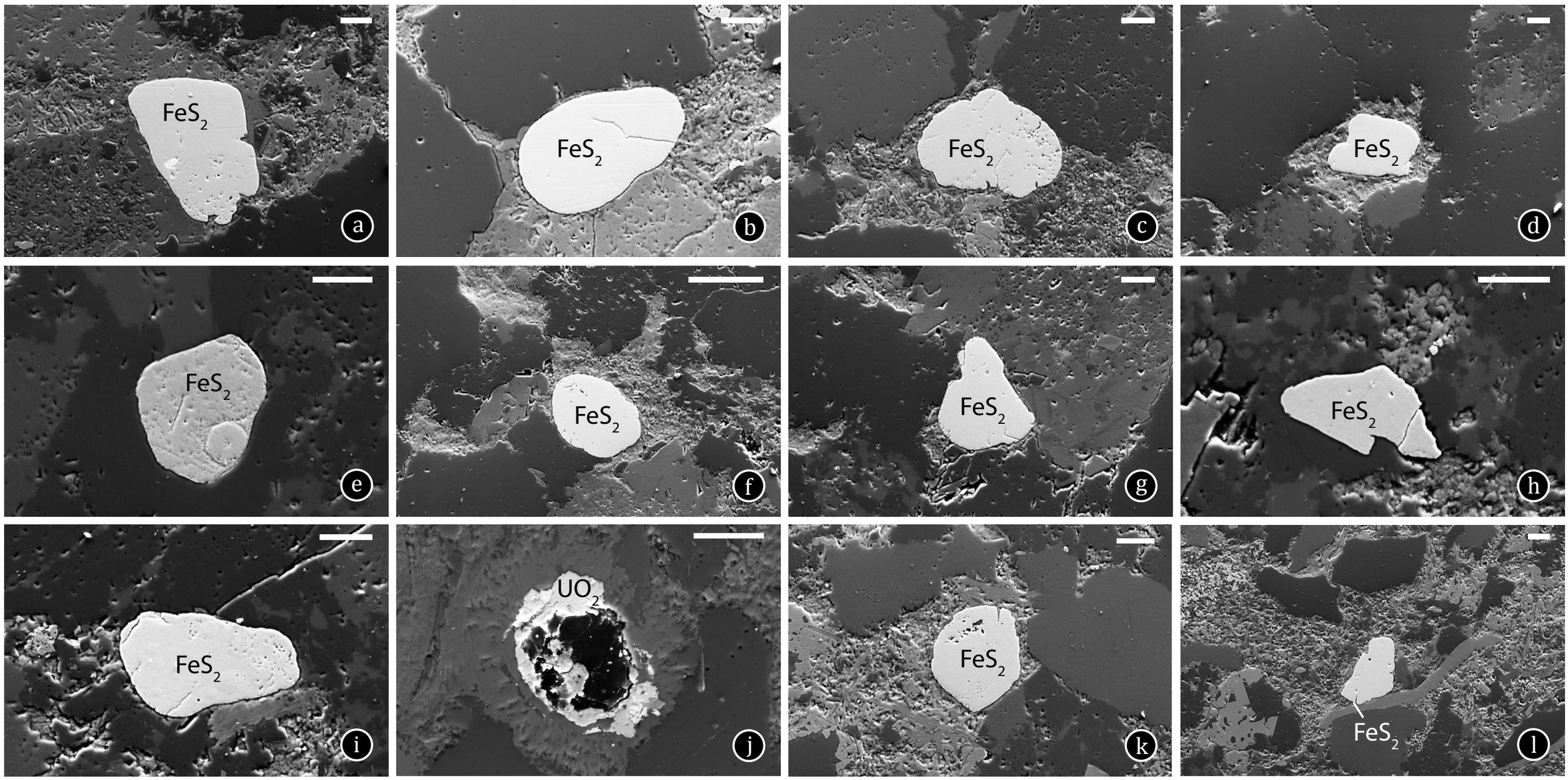


Uraninite

$$UO_2 + {}^{1}/_{2}\,O_2 + 2HCO_3^- \rightarrow UO_2(CO_3)_2^{2-} + H_2O$$

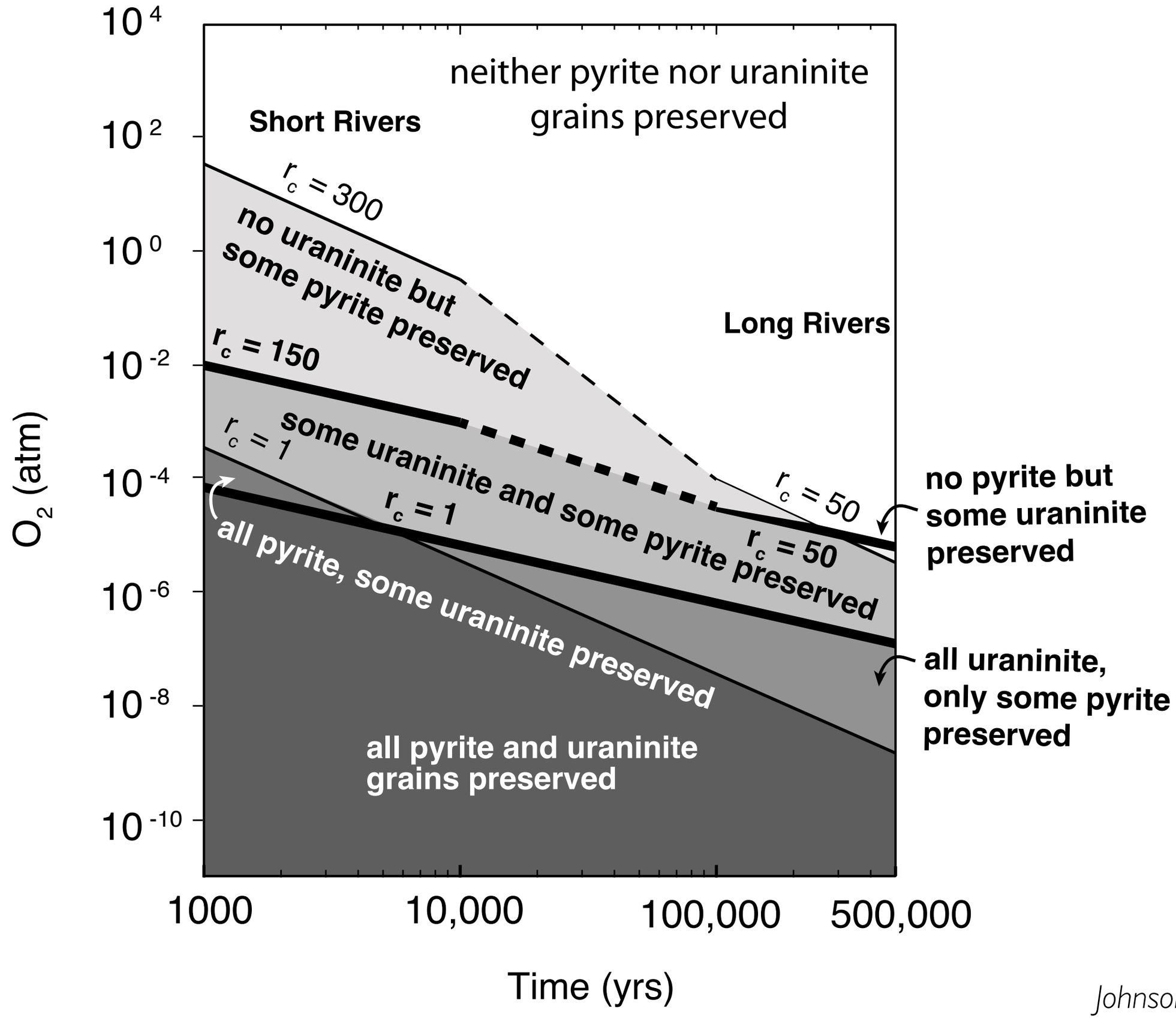

GTF01
20 m
60 m
100 m
140 m
220 m
260 m
300 m
a
b
78m
c
85m
d
e
f
g
h
163m
i
j
183m
k
l
204m
mud
silt
sand
breccia
Ongeluk Formation
Makganyene Formation
Rooinekke Formation
Heynskop Formation
Naragas Formation
Doradale Formation
Pannetjie Formation
Griquatown Iron Formation
ferrous-rich iron formation
ferric-rich iron formation
shale/siltstone
sandstone
carbonate
diamictite
volcanics
ferric-rich nodules
chert nodules
cross-stratification/ scour
ripples
stromatolites

Detrital pyrite and uraninite found throughout these sandstones



Johnson et al. 2014

Paleozoic and Archean conditions; pCO_2 = 0.1atm

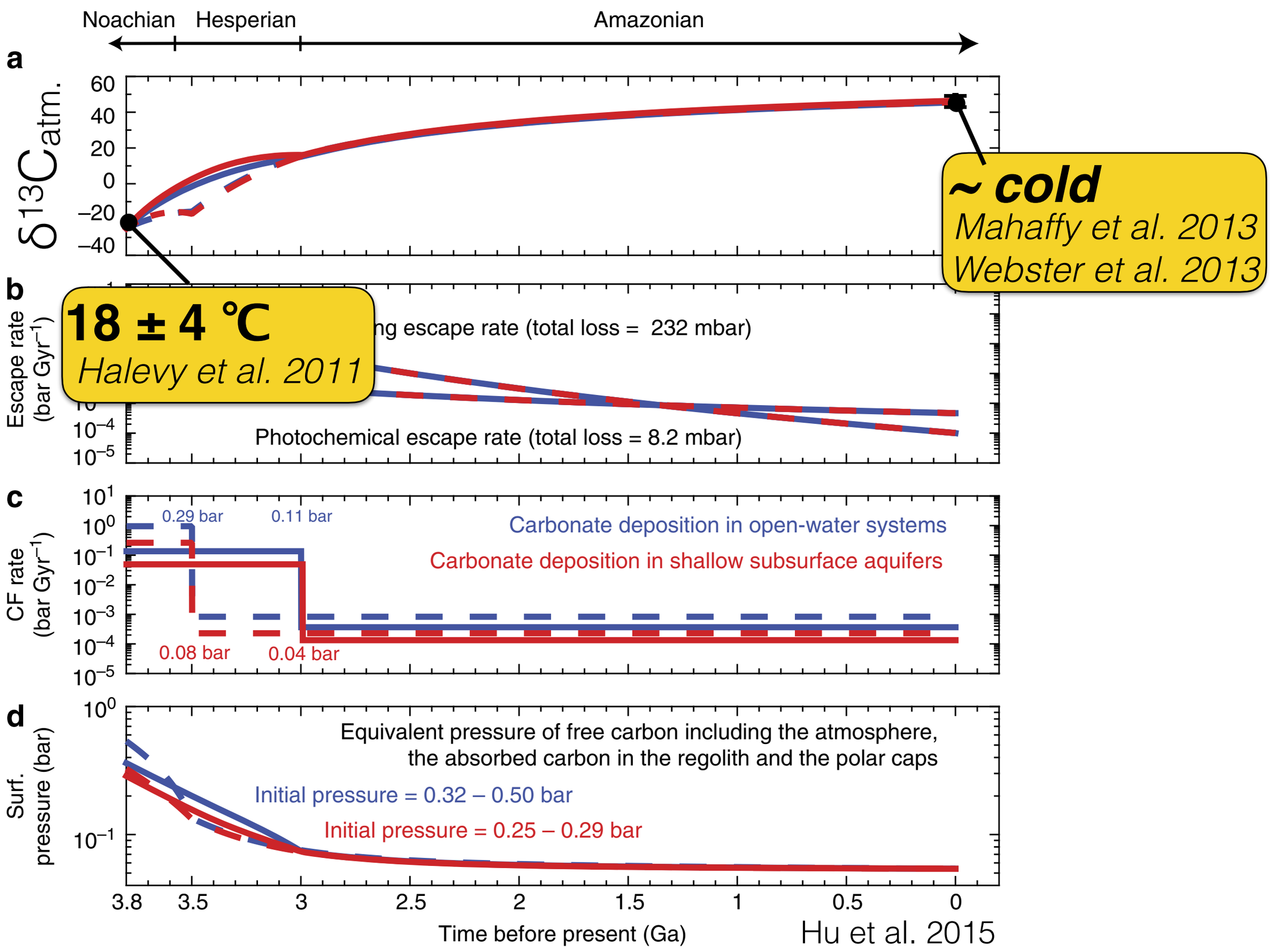


Johnson et al. 2014

Carbonates provide a material of uniquely high geological value

1. O isotopes
   - water budget, climate, temperature.
2. C isotopes
   - carbon cycling and burial, escape, FYS paradox
3. Geochronology
   - U/Pb, Pb/Pb, Sm/Nd
4. Clumped isotopes
   - precipitation temperature, mechanics, taphonomy
5. Body fossils, Trace fossils (microbial laminae)
   - direct record of ancient life

Carbonate isotopes and Mars carbon cycle and climate history



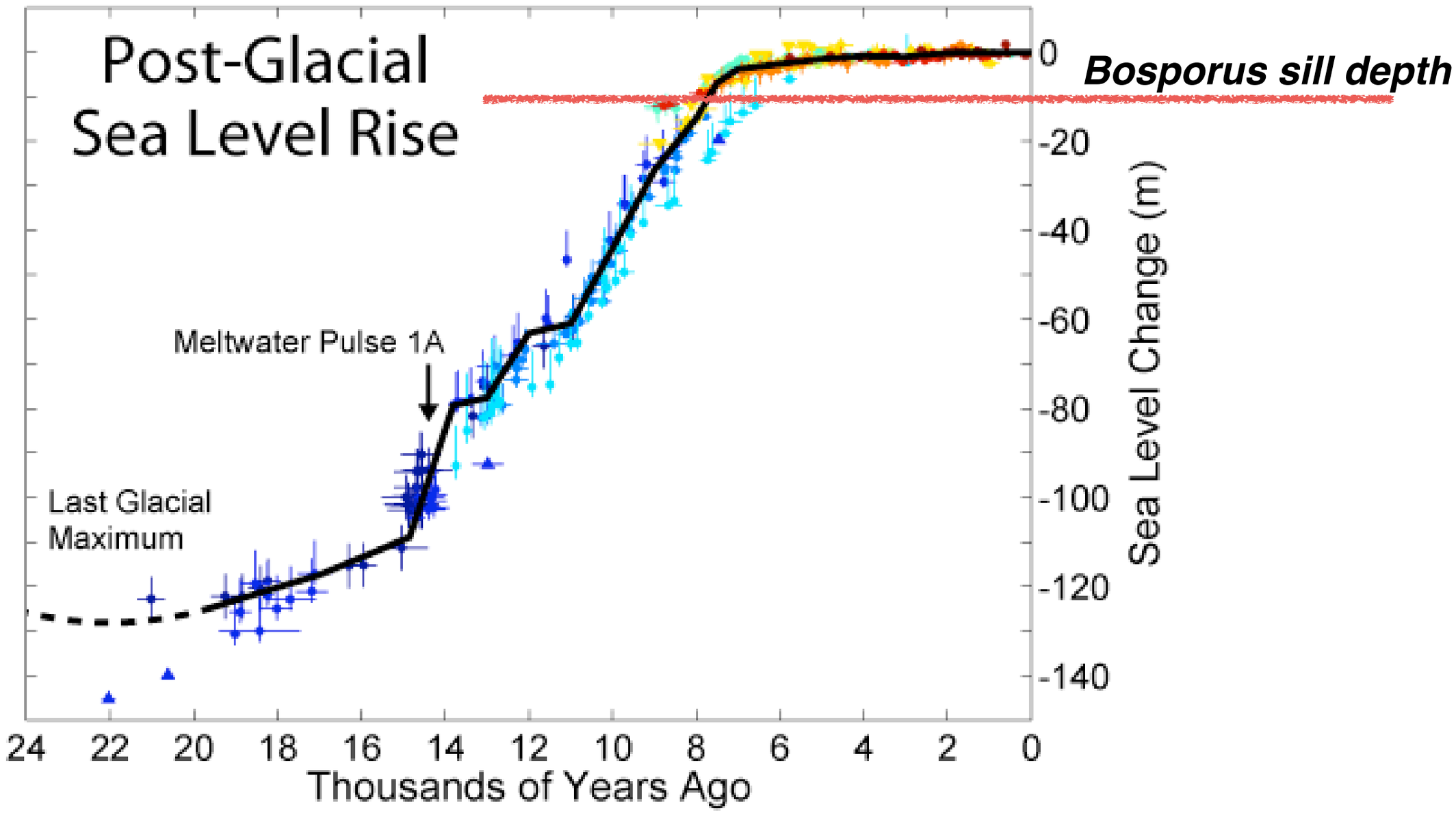
18 ± 4 ℃
Halevy et al. 2011

~ cold
Mahaffy et al. 2013
Webster et al. 2013

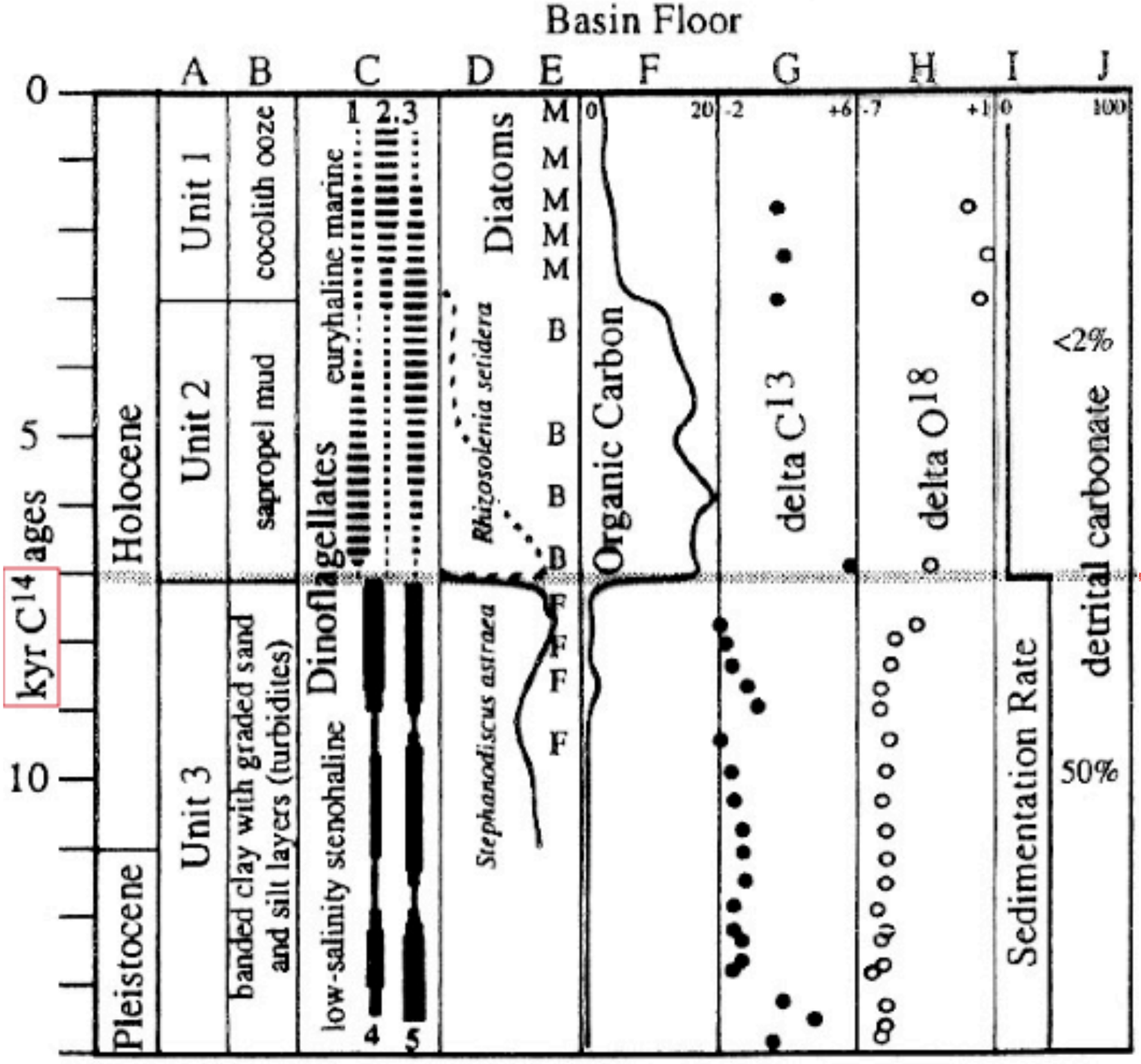
An example from the Black Sea


Black Sea
Bosporus
Sea of Marmara

An empirical sea level curve from coral reefs



Cores from the western Black Sea sediments



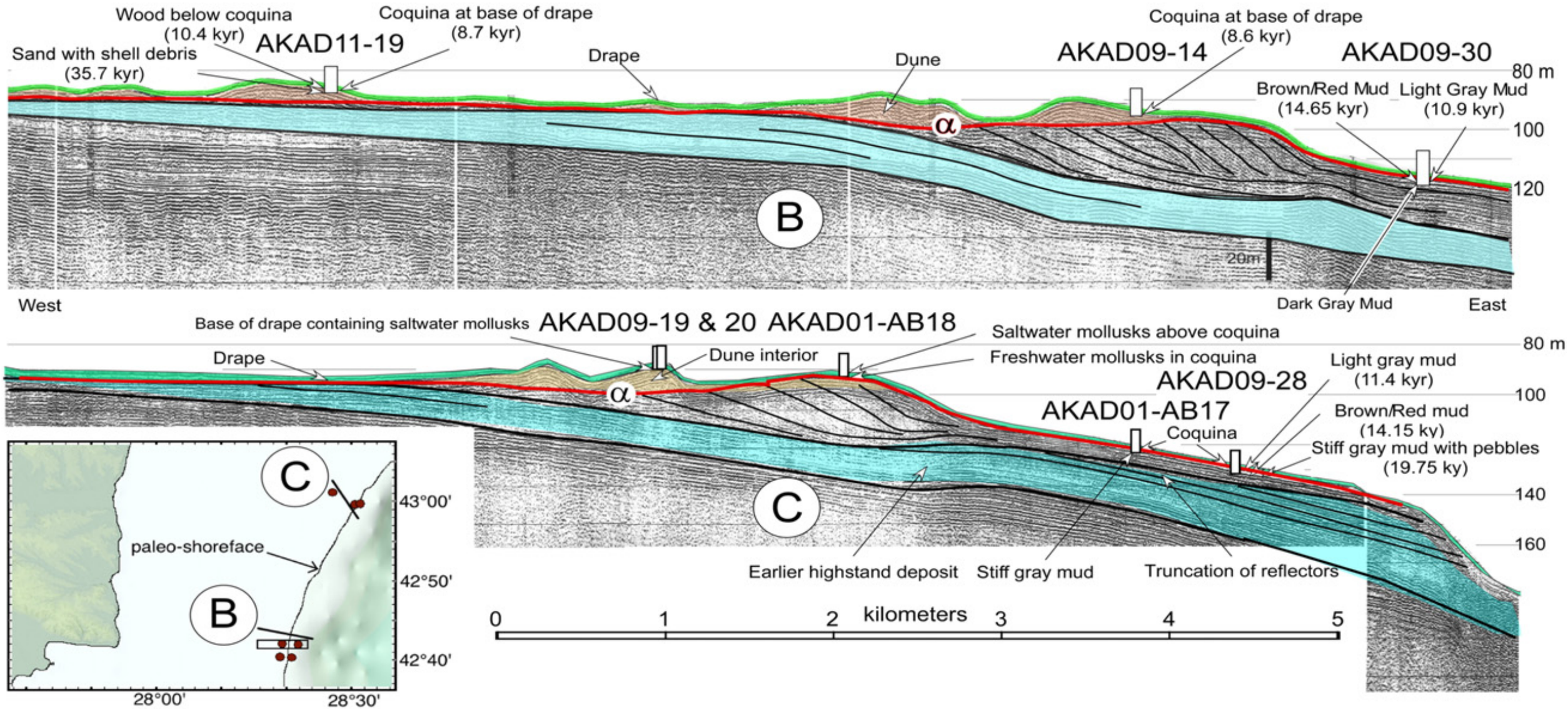
Ryan et al. 1997

Marine

Lacustrine

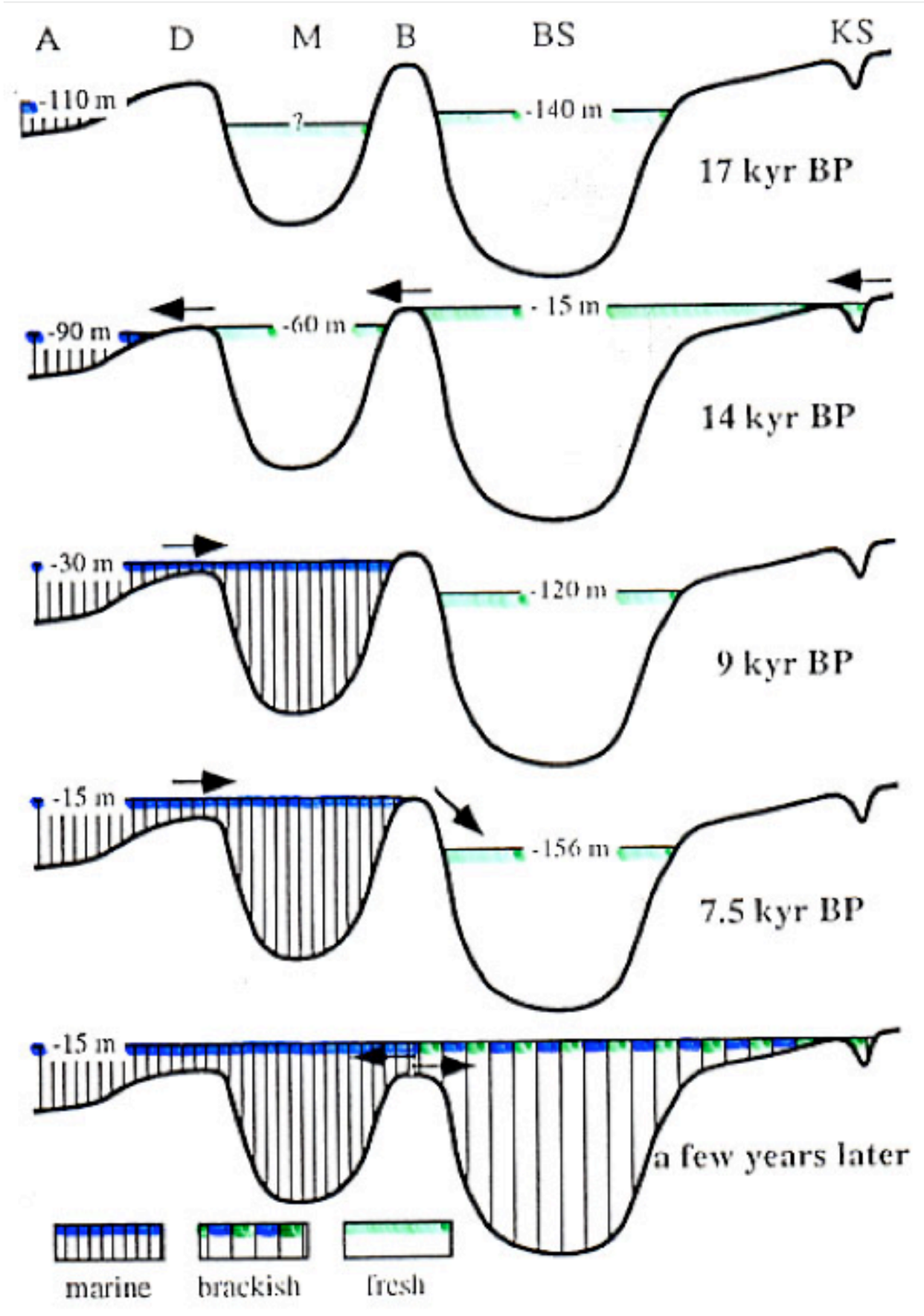
Glacial freshwater fluxes create a "New Euxine Lake"

Sedimentology and stratigraphy allow reconstruction of lake levels



Yanchilina et al. 2017

Sedimentology and stratigraphy allow reconstruction of lake levels



“Lake Jezero" may have been able to get rid of it’s salt. (e.g. sulfate, chloride)

Deltaic sedimentary deposits provide a rich opportunity to observe and quantify the interactions of fluid Mars (water and atmosphere) with the ancient crust. This is not limited to study of clastic materials, sedimentology and strata architecture, but also extends to authigenic phases that record diverse aspects of the paleoenvironmental chemistry, element cycling, and climate.

On Earth, these environments are replete with “biosignatures” and constitute much of our record of the history of life.